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Antivibration Element

Background of the Invention

An antivibration element is disclosed in United States  
5 Patent 5,368,107 which includes a coil spring. The coil spring  
is fixed at its ends on an elastic guide element by means of  
mounts. The damping action of this antivibration element is the  
same for every load condition because of the linear  
characteristic line. For reasons of vibration, it is desirable  
10 that the antivibration element have a low spring constant in the  
unloaded state; whereas, under load, the element should be as  
stiff as possible, that is, the spring constant should be as high  
as possible.

Summary of the Invention

15 It is an object of the invention to provide an antivibration  
element of the kind described above wherein the entire  
antivibration element has a different spring constant for  
different states of loading.

The antivibration element of the invention includes: a coil  
20 spring having an end section and a transition section extending  
from the end section; a guide member; the end section fixed to  
the guide member; and, the transition section being guided on the  
guide member with play.

The coil spring is fixed at its end sections. The  
25 transition section borders on the end section in a direction  
toward the center portion of the coil spring. In the unloaded  
state, the transition section has play with respect to the guide.  
The play can be radial and/or axial. The turns of the transition  
section thereby contribute to the spring action. With the  
30 deformation of the spring under load, the play is overcome and

the turns are at least partially in contact engagement against the guide in the transition section and therefore no longer contribute to the spring action. In this way, the spring stiffness of the coil spring is increased. With different configurations of the guide, a load-dependent damping action can be achieved which is adapted to the particular application. The adaptation of the spring stiffness can take place in dependence upon direction, for example, in that different play is provided in the axial and radial directions.

It is practical to fix the end section to the guide so that it is form tight thereon. The end section can extend over a 3/4 turn to 2 turns and extends especially approximately over 1-1/4 turns of the coil spring. In this way, the coil spring is adequately fixed. At the same time, the number of spring-acting turns is comparatively large for a pre-given spring length. The transition section advantageously extends over approximately 1 to 4 turns. The spring stiffness can be adequately varied in this way. An adequate movability of the spring in the non-guided region is simultaneously ensured.

In order to obtain different spring stiffnesses in different directions, the two ends of the coil spring are twisted toward each other, especially, approximately by a half turn. In order to make possible an adequate variation of the spring constant, the coil spring is guided at both end sections with play in the region of the transition section.

The guide is formed on a plug projecting into the interior of the coil spring and this plug has a receptacle for an attachment means. However, a guide on the outer side of the coil spring can be practical. The guide is advantageously configured as a spirally-shaped slot wherein the turns of the coil spring

are guided. The assembly of the guide in the coil spring can be effected in this way by a simple threaded engaging. A spirally-shaped slot of this kind is easy to produce with low manufacturing tolerances. The distance of the base of the slot to the longitudinal center axis of the coil spring decreases in the transition section with increasing distance from the end section. The play in the transition section therefore increases in a direction toward the center portion of the coil spring.

With increasing load and with the increasing deformation resulting therefrom, more turns come continuously into contact engagement against the guide so that the spring constant increases in correspondence to the reduction of the spacing. In this way, a good guide characteristic of the work apparatus is achieved.

The slot advantageously has a trapezoidally-shaped cross section which is easy to produce. The flanks of the slot and the longitudinal center axis of the coil spring conjointly form an angle which is less than  $90^\circ$ . This angle especially amounts to approximately  $30^\circ$  to  $80^\circ$ . With increasing deformation of the coil spring, the play therefore becomes less in axial direction. It can, however, be practical that the slot have the shape of a segment of a circle when viewed in cross section. In this way, another course of the spring stiffness is achieved. With the variation of the slot cross section, different courses of spring stiffness can be realized in dependence upon the deformation path and the deformation direction.

#### Brief Description of the Drawings

The invention will now be described with reference to the drawings wherein:

FIG. 1 is a perspective view of the antivibration element of

the invention in the unloaded state;

FIG. 2 is a longitudinal section taken through the antivibration element of FIG. 1;

5 FIG. 3 is a schematic showing a guide of the antivibration element of FIG. 2 for an unloaded coil spring;

FIG. 4 is a schematic of the guide element of FIG. 3 with the coil spring under load;

FIG. 5 is a perspective view of the antivibration element of FIG. 1 with a single axis deformation;

10 FIG. 6 is a section view taken through the antivibration element of FIG. 5;

FIG. 7 is a schematic of the antivibration element of FIG. 1 under a two-axis deformation;

15 FIG. 8 is a section view taken through the antivibration element of FIG. 7;

FIG. 9 is a perspective view of the antivibration element of FIG. 1 for a deformation and compressive action in the longitudinal direction;

20 FIG. 10 is a section view through the antivibration element of FIG. 9;

FIG. 11 is a perspective view of the antivibration element of FIG. 1 during deformation and expansion;

FIG. 12 is a section view taken through the antivibration element of FIG. 11;

25 FIG. 13 is a section view of a plug with a coil spring;

FIG. 14 is a force/displacement diagram for the plug of FIG. 13;

FIG. 15 shows the spring stiffness plotted as a function of the deformation for the plug of FIG. 13; and,

30 FIGS. 16 to 23 show variations for the guide in section.

Description of the Preferred Embodiments of the Invention

The antivibration element 1 is shown in a perspective view in FIG. 1 and includes a coil spring 2 guided at its two ends on respective plugs (3, 4). As shown in FIG. 2, the plugs (3, 4) 5 extend into the interior of the coil spring 2. Each plug (3, 4) includes a spirally-shaped slot (9, 10) which forms the guide for the coil spring 2. The coil spring 2 is guided with its end sections (7, 8) form tight in the slots (9, 10), respectively. The end sections (7, 8) extend over a 3/4-turn to two turns and 10 especially over approximately 1 and 1/4-turns of the coil spring 2. The number of turns is measured from the ends 5 and 6 of the coil spring 2 shown in FIG. 1. Transition sections 11 and 12 extend from end sections 7 and 8, respectively and extend over approximately 1 to 4 turns. The coil spring 2 is guided 15 with play in the slots 9 and 10 at the transition sections 11 and 12, respectively.

The slot 9 is configured in the plug 3 and has a trapezoidally-shaped cross section. The slot base 15 runs approximately parallel to the longitudinal axis 13 of the coil 20 spring 2. The flanks 16 and 17 delimit the slot 9 in the direction of the longitudinal axis 13. The flanks 16 and 17 are inclined at an angle  $\alpha$  to the longitudinal axis 13. Correspondingly, the slot 10, which is formed in plug 4, has a slot base 18 which runs parallel to the longitudinal axis 13. 25 The slot 10 also has flanks 19 and 20 which are inclined at an angle  $\alpha$  to the longitudinal axis 13. The angle  $\alpha$  is less than  $90^\circ$  and is especially approximately  $30^\circ$  to  $80^\circ$ . The slot bases (15, 18) each have a play (b) to the coil spring 2. The play (b) increases with increasing distance from the end 30 sections (7, 8). As shown in FIG. 2, the play (b) increases in

the course of a half turn of the coil spring 2 to the play (b'). As shown in FIG. 3, the distance (a) of the slot base 15 to the longitudinal axis 13 of the coil spring decreases to the distance a'. The line 23 is formed by the course of the base 15 of the slot in the transition section 1 and this line thereby runs conically in a direction toward the center of the coil spring 2.

5 In the axial direction, the coil spring 2 has play (c) to the flank 16 and has play (d) to flank 17. Accordingly, the coil 10 spring 2 has play relative to the plug 3 in radial and axial direction in the transition section 11. The coil spring 2 has the corresponding play in the transition section 12 to the plug 4. The plugs 3 and 4 can, however, be configured to be 15 different so that the transition sections 11 and 12 have different play to the plugs 3 and 4 in the axial and/or radial directions.

In a deformation of the coil spring 2 as shown in FIG. 4, the spacing of the coil spring 2 to the guide 9 reduces on the 20 bending outer end 21. As shown in FIG. 4, the coil spring 2 lies against the slot base 15. The turn which is in contact engagement does not contribute any longer to the spring action. The number of spring-acting turns is reduced and therefore the 25 spring stiffness of the coil spring 2 is increased. At the bending end 22, the play in the slot base 15 increases to the play b''. The coil spring 2 lies against the first flank 16 while the play d' to the second flank 17 is increased relative to the unloaded state.

30 For fixing the coil spring, for example, in a portable handheld work apparatus, one end of the coil spring is fixed to a first housing part and a second end of the coil spring is fixed

to a second housing part. For fixing the coil spring to the housing parts (not shown), the plugs (3, 4) each have longitudinal bores 14 which function to accommodate an attachment means. This means can, for example, be a pin projecting into the 5 longitudinal bore 14. However, it can be practical to provide an internal thread on the inner bore 14 and to threadably engage a screw into a plug 3 or 4 for fixing. The first housing part can, for example, be a component connected to the drive motor of the work apparatus while the second housing component can be 10 connected to the handle of the work apparatus.

In FIGS. 5 and 6, the antivibration element 1 is deformed perpendicularly to the longitudinal center axis 24 of the plug 3 and the longitudinal center axis 25 of plug 4. In FIGS. 5 and 6, the deformation is 7 mm in the direction of the X-axis. The 15 longitudinal center axis 25 of the plug 4 is therefore displaced by 7 mm in the direction of the X-axis with respect to the longitudinal center axis 24 of the plug 3. As shown in FIG. 6, the Z-axis runs in the direction of the longitudinal center axes 24 and 25 and the Y-axis extends perpendicularly into the 20 plane of the drawing. With the deformation, the distance of the coil spring 2 to the plugs 3 and 4 in the slot base is increased by the deformation on the bending inner side 22. The coil spring 2 lies against the flank 16 of the slot 9 while play is present with respect to flank 17. The same applies for the 25 bending inner side 22 and the plug 4. The coil spring 21 lies against corresponding plugs 3 and 4 on the bending outer side 21. The number of spring-acting turns of the coil spring 2 is thereby reduced and the spring stiffness is increased compared to the unloaded state.

30 In FIGS. 7 and 8, the antivibration element 1 is shown for a

deformation of 7 mm in the X-direction and, in the Y-direction, of -7 mm. The longitudinal center axis 24 of the plug 3 includes a spacing of 7 mm with respect to the longitudinal center axis 25 of the plug 4 in the X-direction as well as in the Y-direction.

5 Here too, the turns of the bending outer side 21 lie on each of the plugs 3 and 4 so that the number of spring-acting turns is reduced relative to the unloaded state and the spring constant is increased.

In FIGS. 9 and 10, the antivibration element 1 is, in  
10 addition to the deformation in the X-direction by 7 mm and the deformation in the Y-direction by -7 mm, shortened by 5 mm in the direction of the Z-axis and, in FIGS. 11 and 12, the antivibration element 1 is lengthened additionally by 5 mm. As shown in FIG. 10, the spring constant of the coil spring 2 is  
15 further reduced when there is an intense deformation and shortening of the antivibration element. This is achieved in that the turns of the coil spring 2 in a region 54 of the coil spring bordering on the transition section 11 are in contact engagement with each other. The turns lie, as above, against the  
20 plugs 3 and 4. In contrast to this, in the extension of the antivibration element 1 shown in FIGS. 11 and 12, the turns of the coil spring 2 already have a radial play (b) and an axial play (c) and (d) in the transition sections 11 and 12. Accordingly, in the deformation state shown in FIGS. 11 and 12,  
25 the spring constant of the coil spring 2 is less than in the deformation state shown in FIGS. 9 and 10.

In FIG. 13, a plug 26 having a slot 27 is shown wherein a coil spring 2 is guided. The slot 27 has an approximately circular-shaped cross section which has a play (e) to the coil  
30 spring 2 in the axial and radial directions in a transition

section 11 of the coil spring 2. In FIG. 14, the force/displacement diagram for an antivibration element having a plug 26 is shown and, in FIG. 15, the course of the spring constant C is shown plotted as a function of displacement (s).

5 In region 30, the force F to displacement (s) runs as indicated by line 28 approximately constant. In this region of the deformation, the turns in the transition regions 11 and 12 of the coil spring are movable relative to the guide and therefore have a play to the slot 27. In the bordering region 32 and starting 10 from the end sections 7 and 8, the turns of the coil spring 2 lie more and more against the guide in the transition regions 11 and 12. The force, which is necessary for deforming the coil spring 2, increases overproportionally in the region 32. The course of the spring constant C is shown by line 29 in FIG. 15.

15 As shown in FIG. 15, the spring constant C runs approximately constant in the region 31 which corresponds to the region 30 in FIG. 14. With increasing deformation, the spring constant C increases in the regions 33 which correspond to the regions 32 in FIG. 14. If all turns lie against the guide in the transition 20 region, then the spring constant C remains constant in the regions 35. In the corresponding region 34 of the line 28, the force F, which is necessary for deformation, remains proportional to the deformation displacement (s).

25 The slot, in which the coil spring 2 is guided in the transition region, can have the most different cross-sectional forms adapted to the particular application. The slot 36, which is shown in cross section in FIG. 16, has in its upper region 55 flanks 56 and 57, which run perpendicular to the longitudinal axis 13 of the coil spring 2. In a lower region 58 extending 30 directly therefrom, the slot 36 has a circular-shaped cross

section. With slight deformation, the coil spring 2 is in the upper region 55 of the slot 36 and has axial play (f) to the flanks 56 and 57. For a deformation of the coil spring 2 and for a reduction of the radial play caused thereby, the axial play (f) 5 reduces to a value  $f'$  as soon as the coil spring 2 is in the lower region 58. The spring stiffness C increases greatly thereby with deformation of the coil spring 2.

In FIG. 17, a slot 37 is shown having a trapezoidally-shaped cross section. The flanks 52 and 53 of the slot 37 are inclined 10 relative to the longitudinal axis 13 of the coil spring 2 by an angle  $\beta$  which corresponds to approximately  $45^\circ$ . With the variation of the angle  $\beta$ , the increase of the spring stiffness C can be adjusted when the coil spring 2 is deformed.

In FIG. 18, a slot 38 is shown which, in an upper region 59, 15 has flanks 61 and 62 which run parallel to each other and which run perpendicular to the longitudinal axis 13 of the coil spring 2. In a lower region 60, the slot 38 is configured to have a circular-arc shape. The coil spring 2 is guided in the slot 38 with a radial play but without axial play.

FIG. 19 shows a slot 39 having an approximately quadratic cross section. The coil spring 2 has a play (g) to the flanks 63 and 64 and to the slot base 65. The distance between spring and slot can be equal in all directions or it can be different 20 depending upon direction. Rectangular-shaped slot cross sections can also be advantageous.

In FIG. 20, a slot 40 is shown which has only a slight axial play in an upper region 66. The flanks of the slot 40 run 25 perpendicular to the longitudinal axis of the coil spring 2 in this region and parallel to each other. The coil spring 2 is guided tightly between the flanks in axial direction. In a lower

region 67, the slot 40 expands in the axial direction so that, for increasing deformation, the play in the axial direction increases whereas, the play in the radial direction decreases because of the reduced spacing.

5 FIG. 21 shows a slot 41 which, in an upper region 68, has a large axial play and, in a center region 69, very slight axial play and, in a lower region 70, has large axial play. For this purpose, in the center region 69, the slot 41 is constricted. The spring stiffness does not increase continuously but reduces 10 again as soon as the coil spring 2 is in the lower region 70.

In the slot 42 shown in FIG. 22, the coil spring 2 is tightly guided in an upper region 71 in axial direction. Axial play is not present in the upper region 71. In a lower region 72, the slot 42 first widens in order to then again 15 narrow. The slot 42 has an approximately hexagonally-shaped cross section in the lower region 72.

The slot 43 shown in FIG. 23 has an approximately circular-arc shaped cross section. The cross section of the slot 43 can, however, also be configured to be elliptical. 20 Depending upon the desired change of the spring constant C and the permitted maximum deformation, other cross sections of the guide can be practical. The cross section can be adapted to the wanted progression of the characteristic line of the antivibration element. Instead of providing a plug for a guide, 25 the coil spring 2 can also be guided on its periphery. The progression of the antivibration element can likewise be adjusted via the conicity of the slot spiral. A direction-dependent progression can be achieved in that the ends 5 and 6 of the coil spring are rotated relative to each other. Also, a depth, which 30 is different in different directions, and/or a wide slot spiral

can be advantageous.

It is understood that the foregoing description is that of the preferred embodiments of the invention and that various changes and modifications may be made thereto without departing 5 from the spirit and scope of the invention as defined in the appended claims.